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(54) Apparatus and method for testing bank-notes

Vorrichtung und Verfahren zum Prüfen von Banknoten

Appareil et procédé de validation de billets de banque

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- **DATABASE WPI Week 9406, Derwent Publications Ltd., London, GB; AN 94-174353 & NL-A-9 201 701 (ENSCHEDE)**

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Description

This invention relates to apparatus for testing bank-notes. The invention also relates to a method for testing bank-notes. It should be understood that term "bank-note" used herein is to be taken to include currency bills and other valuable documents such as traveller's cheques, for example.

Various techniques are known for testing the authenticity of bank-notes. Typically, such techniques involve analyzing the colour response of light which may be reflected from a bank-note being tested, to determine whether there is a sufficient degree of correspondence with the colour response of a genuine bank-note.

However, the range of colours acceptable for bank-notes is limited. Also, colour photocopiers may be used to produce counterfeit bank-notes, and the pigments used in such colour photocopiers are liable to change. Furthermore, bank-notes which have been in use for some time may become dirty or stained in various ways, such that their colour properties are altered. Such testing techniques, based on colour response, therefore have the disadvantage of unduly limited reliability.

NL-A-9201701 discloses an arrangement whereby an original document, such as a bank-note, can be provided with a code-image at the time of printing thereof which code-image is invisible to the human eye but will be reproduced if the document is copied by way of a photocopier such as a digital colour photocopier. The arrangement therefore provides a means whereby documents such as bank-notes can be printed with invisible code-images which will show up later on a photocopy thereof and so that any attempted forgery then becomes readily identifiable by the human eye. This arrangement is however disadvantageous in that it relies upon attempted photocopying of the original document to recreate the coded image and, yet further, relies on the human eye to detect attempted forgery.

EP-A-0537513 discloses an arrangement for validating bank-notes and which merely employs a charge-coupled-device sensor for receiving linear images of a bank-note. However, the manner in which a forged bank-note is actually detected is disadvantageously limited.

It is an object of the present invention to provide a method and apparatus for testing bank-notes which alleviates the above-discussed disadvantages.

Therefore, according to one aspect of the present invention, there is provided apparatus for testing bank-notes for genuineness, characterized by: image forming means adapted to form a digital image of an area on a bank-note; processing means adapted to compute a Fourier transform of said digital image; and analysing means adapted to analyse said Fourier transform and identify the bank-note being tested as genuine or non-genuine in dependence on the result of the analysis.

According to another aspect of the present invention, there is provided a method of testing a bank-note for genuineness, characterized by the steps of: forming a digital image of an area on said bank-note, computing a Fourier transform of the digital image; and analyzing the Fourier transform to identify a bank-note as genuine or non-genuine depending on the result of the analysis.

It will be appreciated that the apparatus and method for testing bank-notes, according to the invention, have the advantage of avoiding the use of colour response analysis, by virtue of the specified Fourier transform feature. As will be explained in more detail hereinafter, the apparatus and method according to the invention are particularly effective for identifying counterfeit notes produced by commonly used reproduction techniques such as colour photocopiers or offset lithography printing.

Embodiments of the present invention will now be described by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a simplified block diagram of apparatus according to the invention for detecting forged bank-notes;
Fig. 2 is a flowchart illustrating the operation of the apparatus shown in Fig. 1:
Fig. 3 is a block diagram of a modification of a portion of the apparatus shown in Fig. 1; and
Fig. 4 is a block diagram of another modification of a portion of the apparatus shown in Fig. 1.

Referring now to Fig. 1, there is shown a simplified block diagram of apparatus 10 according to the invention for testing the authenticity of bank-notes, sometimes referred to as currency bills. The apparatus 10 includes a drive device 12 arranged to feed a bank-note 14 to be tested in the direction of arrow 16. Light from a white light source 18 is directed towards the bank-note 14, which is fed past a CCD (charge coupled device) camera 20 with which is associated a camera control unit 22. Although a CCD camera is used in the described embodiment, other types of electronic camera may be utilized. The camera control unit 22 causes the CCD camera 20 to image a selected small area, of the bank-note 14, typically a square area about 10-20 millimetres across. Preferably, the area selected has a high level of printing thereon, since it will be appreciated that areas with a low level of printing are less suitable for distinguishing forgeries from genuine notes. The camera 20 provides a digitized representation of the imaged area, which is fed to an image memory 24 for storage therein as a digital image. That is, each pixel is stored in the form of a binary number representing the brightness of the pixel as detected by the CCD camera 20.

The image memory 24 is connected to a Fourier transform processor 26 which forms the two-dimensional Fourier transform of the digital image stored in the image memory 24. The Fourier transform processor 26 may be a dedicated hardware digital logic device such as a Fast Fourier Transform (FFT) processor, or may be a suitably programmed microprocessor. The thus com-

puted Fourier transform is stored in a memory device 28. The memory device 28 is connected to an analyzer 30 which analyzes the Fourier transform stored in the memory device 28 to determine whether or not the stored Fourier transform has features which identify the bank-note being tested as counterfeit. A signal representing the result of the analysis is provided on an output line 32.

Referring to Fig. 2 there is shown a flowchart 50 illustrating steps involved in the above described operation of the apparatus 10 shown in Fig. 1. Firstly as shown in block 52, a digital image of an area of the bank-note 14 (Fig 1) is captured by the CCD camera 20. The computed digital image is stored in the image memory as shown in block 54. Next, the two-dimensional Fourier transform of the stored digital image is computed (block 56) by the Fourier transform processor 26 and stored (block 58) in the memory device 28. Finally, Fourier transform analysis is performed (block 60) in the analyzer 30, as will now be explained in detail.

With regard to the operation of the analyzer 30, it should first be appreciated that there are, or course, many different procedures which may be used to produce counterfeit bank-notes. For example, one procedure is to use a colour photocopier. It has been found that copies produced by colour photocopiers have a regular pattern of closely spaced straight lines therein. The spacing of these lines is sufficiently small such that this pattern is not generally visible to the unaided eye. Another procedure which may be used to produce counterfeit bank-notes involves the use of offset lithography printing. In this connection, it should be understood that genuine bank-notes are generally produced by printing processes such as photogravure, rather than offset lithography printing. It has been found that offset lithography printing results in a counterfeit bank-note which has a regular pattern of closely spaced dots therein, which again is generally invisible to the unaided eye. The printing processes, such as photogravure, currently used for printing genuine bank-notes do not have any such closely spaced regular patterns that extend over the whole bank-note. Such localized patterns as do exist on genuine engraved bank-notes will have larger spacings than the features which are detected by the Fourier transform procedure described herein. The resolution of the digital image stored in the image memory 24 should be sufficiently high, to resolve the closely spaced lines or dots just discussed. Preferably, the pixel spacing in the captured digital image is less than or equal to one-half of the spacing of the regular dot-lines pattern. A resolution of around 100 microns is a typical value.

Computing the Fourier transform of the digital image stored in the image memory 24 has the effect of clearly revealing the spatial frequencies of regular patterns on the bank-note, particularly the features that are present in counterfeit notes produced by commonly used reproduction techniques as discussed hereinabove. If the bank-note 14 being tested has a regular closely spaced pattern thereon, such as lines or dots, then the Fourier transform pattern will have relatively high spatial frequency components therein. The more closely spaced the elements of the regular pattern are, the higher will be the spatial frequencies in the Fourier transform. That is, the further will the characteristic peaks in the transform be displaced from the centre (corresponding to zero spatial frequency) of the Fourier transform pattern. The Fourier transform pattern may consist of one or more radial lines of spots, dependent on the nature of the regular pattern of lines or dots, etc., on the bank-note being tested.

The analyzer 30 is effective to determine whether or not high spatial frequency components, typically in the form of a radial line or lines of spots, extending outwards from the origin (central location), exists in the Fourier transform pattern stored in the memory 28. This is preferably achieved by a known pattern recognition technique. For example, the Fourier transform pattern can be tested for large signals or spots at an appropriately large distance from the origin.

In an alternative arrangement, Fig. 3, an analyzer 130 (corresponding to the analyzer 30) includes a storage device 80 which stores the Fourier transform of the same selected area on a genuine bank-note, as is formed by the camera 20 for a bank-note being tested. A comparator 82 compares the Fourier transform from the memory 28 with the Fourier transform of the genuine bank-note, from the storage device 80, to provide an output on a line 132 (corresponding to the line 32 in Fig. 1) if at least a predetermined difference exists, indicative of the bank-note 14 being tested being counterfeit.

Fig. 4 shows a portion of the apparatus shown in Fig. 1, modified in accordance with a further modified embodiment of the invention. In this modified embodiment an averaging device 210 is disposed between the Fourier transform memory 28 and the analyzer 30. The camera control unit 22 is arranged to cause the camera 20 to image successively a plurality of different small areas of the bank-note 14 being tested. The Fourier transforms for these areas are successively generated, stored in the memory 28, and sent to an averaging device 210, Fig. 4, which computes the average of the successively derived Fourier transforms. It will be appreciated that if the bank-note 14 has a regular pattern, such as lines or dots, thereon, as discussed hereinabove, then such pattern effectively accumulates during the averaging process, whereas the basic print pattern of the bank-note, which varies in frequency over the bank-note, averages out to a low level during the averaging process. This enables the analyzer 30 to more easily determine the presence of spatial frequency components of large amplitude since such components will be relatively strong as a result of the averaging process. It will be appreciated that the ease of operation of the analyzer 30 is enhanced, enabling a more accurate determination to be achieved by pattern recognition techniques, for example. In this connection, it will be appre-

ciated that the large amplitude features that are detected are characteristic of the dot/line pattern created in the counterfeiting process as discussed hereinabove, and the Fourier transform of these features will be substantially constant over the entire note. On a genuine note, the features of the printing will vary with the area examined, and will generally be of lower amplitude and occur at lower spatial frequencies.

There has been described an effective and efficient arrangement for detecting counterfeit bank-notes, particularly where the nature of the counterfeit bank-note is such that a regular pattern, such as a pattern of lines or dots exists in the counterfeit note. The described apparatus will detect counterfeit notes produced by commonly used processes, such as colour photocopying and offset lithography printing. However, it will be appreciated that there are other ways in which bank-notes may be forged, so that in a practical arrangement for authenticating bank-notes it may be desirable to include an additional testing device or devices operating on a different principle from that described herein.

The described apparatus may be incorporated in a bank-note recognition and validation apparatus into which bank-notes are fed by a user of the apparatus. Such apparatus will first recognize a bank-note, i.e. identify the type and denomination of the note. On the basis of the identified note type, a suitable area or areas thereon may be selected using the camera control unit 22 (Fig. 1) for example, for analysis by the Fourier transform procedure described herein.

As a further modification, instead of imaging a square area of the bank-note, a linear area, e.g. a line one pixel wide extending across the bank-note being tested could be imaged and a one-dimensional Fourier transform applied to the stored image instead of a two-dimensional Fourier transform. This has the advantage of requiring considerably less computing power, thereby resulting in cost and/or time savings, but the reliability of the apparatus may be reduced.

Claims

1. Apparatus for testing bank-notes for genuineness, characterized by: image forming means (20,22) adapted to form a digital image of an area on a bank-note (14); processing means (26) adapted to compute a Fourier transform of said digital image; and analyzing means (30) adapted to analyze said Fourier transform and identify the bank-note (14) being tested as genuine or non-genuine in dependence on the result of the analysis.

2. Apparatus according to claim 1, characterized in that said bank-note is identified as non-genuine if said Fourier transform contains high spatial frequency components.

3. Apparatus according to claim 1 or claim 2, characterized in that said analyzing means (30) includes comparison means (82) adapted to compare said Fourier transform with a Fourier transform derived from a genuine bank-note.

4. Apparatus according to claim 1 or claim 2, characterized in that said image forming means (20,22) is adapted to image a plurality of areas on said bank-note (14): in that averaging means (210) is provided adapted to form an average Fourier transform from the Fourier transforms of said plurality of areas; and in that said averaging means (30) is adapted to analyze said average Fourier transform.

5. Apparatus according to any one of the preceding claims, characterized in that said image forming means (20,22) includes a CCD camera (20).

6. A method of testing a bank-note for genuineness, characterized by the steps of: forming a digital image of an area on said bank-note, computing a Fourier transform of the digital image; and analyzing the Fourier transform to identify a bank-note as genuine or non-genuine depending on the result of the analysis.

7. A method according to claim 6, characterized in that said step of analyzing includes detecting high spatial frequency components of said Fourier transform.

8. A method according to claim 6 or claim 7, characterized in that said step of analyzing includes comparing said Fourier transform with a Fourier transform derived from a genuine bank-note.

Patentansprüche

1. Vorrichtung zum Prüfen von Banknoten auf Echtheit, gekennzeichnet durch: ein Bildformungsmittel (20, 22), das dazu eingerichtet ist, ein Digitalbild eines Bereiches einer Banknote (14) zu bilden; ein Verarbeitungsmittel (26), das dazu eingerichtet ist, eine Fourier-Transformierte des Digitalbildes zu berechnen; und ein Analysemittel (30), das dazu eingerichtet ist, die Fourier-Transformierte zu analysieren und in Abhängigkeit vom Ergebnis der Analyse die geprüfte Banknote als echt oder nicht-echt zu identifizieren.

2. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß die Banknote als nicht-echt identifiziert wird, falls die Fourier-Transformierte Komponenten hoher Ortsfrequenzen enthält.

3. Vorrichtung gemäß Anspruch 1 oder Anspruch 2,

dadurch gekennzeichnet, daß das Analysemittel (30) ein Vergleichermittel (80) enthält, das dazu eingerichtet ist, die Fourier-Transformierte mit einer Fourier-Transformierten zu vergleichen, die von einer echten Banknote abgeleitet ist.

4. Vorrichtung gemäß Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß das Bildformungsmittel (20, 22) dazu eingerichtet ist, eine Vielzahl von Bereichen der Banknote (14) abzubilden; daß ein Mittlungsmittel (210) vorgesehen ist, das dazu eingerichtet ist, eine mittlere Fourier-Transformierte aus den Fourier-Transformierten der Vielzahl von Bereichen zu bilden; und daß das Mittlungsmittel (30) dazu eingerichtet ist, die gemittelte Fourier-Transformierte zu analysieren.

5. Vorrichtung gemäß einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das Bildformungsmittel (20, 22) eine CCD-Kamera (20) enthält.

6. Verfahren zum Prüfen von Banknoten auf Echtheit, gekennzeichnet durch die Schritte: Bildung eines Digitalbildes eines Bereiches der Banknote; Berechnung einer Fourier-Transformierten des Digitalbildes; und Analyse der Fourier-Transformierten, um in Abhängigkeit vom Ergebnis der Analyse eine Banknote als echt oder nicht-echt zu identifizieren.

7. Verfahren gemäß Anspruch 6, dadurch gekennzeichnet, daß der Schritt der Analyse eine Erfassung von Komponenten hoher Ortsfrequenzen der Fourier-Transformierten enthält.

8. Verfahren gemäß Anspruch 6 oder Anspruch 7, dadurch gekennzeichnet, daß der Schritt der Analyse einen Vergleich der Fourier-Transformierten mit einer Fourier-Transformierten enthält, die von einer echten Banknote abgeleitet ist.

Revendications

1. Appareil d'examen de l'authenticité des billets de banques, caractérisé par les éléments suivants : un moyen de formation d'image (20, 22) adapté pour former une image numérique d'une zone sur un billet de banque (14); un moyen de traitement (26) adapté pour calculer une transformée de Fourier de ladite image numérique; et un moyen d'analyse (30) adapté pour analyser ladite transformée de Fourier et identifier le billet de banque (14) examiné comme vrai ou faux, selon le résultat de l'analyse.

2. Appareil selon la revendication 1, caractérisé en ce que le billet de banque est identifié comme faux si ladite transformée de Fourier contient des composants de fréquence spatiale élevée.

3. Appareil selon la revendication 1 ou la revendication 2, caractérisé en ce que ledit moyen d'analyse (30) comprend un moyen de comparaison (82) adapté pour comparer ladite transformée de Fourier à une transformée de Fourier dérivée d'un vrai billet de banque.

4. Appareil selon la revendication 1 ou la revendication 2, caractérisé en ce que ledit moyen de formation d'image (20, 22) est adapté pour mettre en image un ensemble de zones sur ledit billet de banque (14) : en ce que ledit système de moyennage (210) est adapté pour construire une transformée moyenne de Fourier à partir des transformées de Fourier desdites plusieurs zones; et en ce que ledit système de moyennage (30) est adapté pour analyser ladite transformée moyenne de Fourier.

5. Appareil selon l'une quelconque des revendications précédentes, caractérisé en ce que ledit moyen de formation d'image (20, 22) comprend une caméra CCD (20).

6. Méthode d'examen de l'authenticité des billets de banque, caractérisée par les phases suivantes : formation d'une image numérique d'une zone sur ledit billet de banque; calcul d'une transformée de Fourier de ladite image numérique; analyse de ladite transformée de Fourier pour identifier le billet de banque examiné comme vrai ou faux, selon le résultat de l'analyse.

7. Méthode selon la revendication 6, caractérisée en ce que ladite phase d'analyse comprenne la détection de composants de ladite transformée de Fourier, dont la fréquence spatiale est élevée.

8. Méthode selon la revendication 6 ou la revendication 7, caractérisée en ce que ladite phase d'analyse englobe la comparaison de ladite transformée de Fourier à une transformée de Fourier dérivée d'un vrai billet de banque.

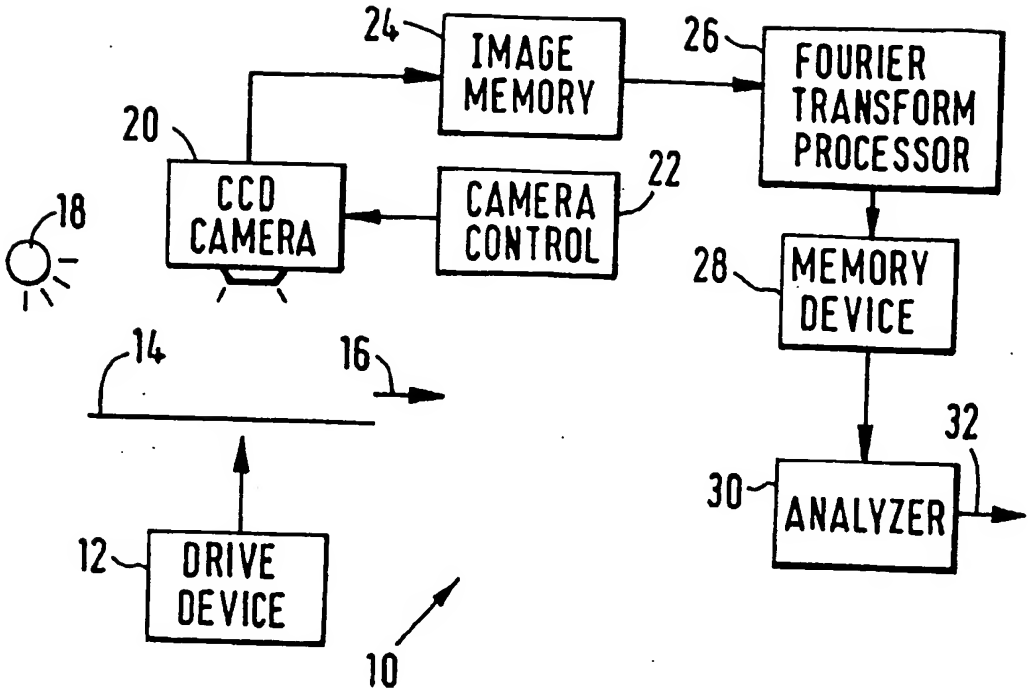

24
IMAGE MEMORY
26
FOURIER TRANSFORM PROCESSOR
20
CCD CAMERA
CAMERA CONTROL
22
18
28
MEMORY DEVICE
14
16
32
30
ANALYZER
12
DRIVE DEVICE
10

FIG.1.

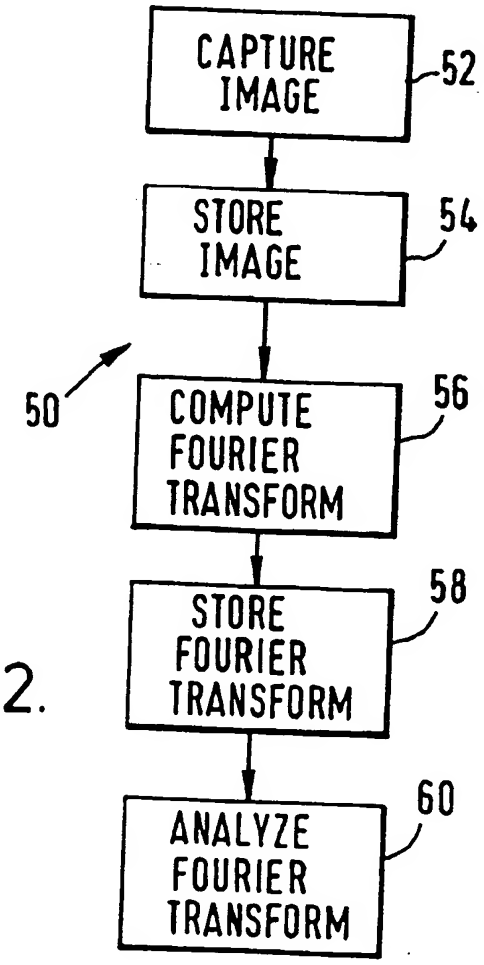

CAPTURE IMAGE
52
STORE IMAGE
54
50
COMPUTE FOURIER TRANSFORM
56
STORE FOURIER TRANSFORM
58
ANALYZE FOURIER TRANSFORM
60

FIG.2.

FIG. 3.

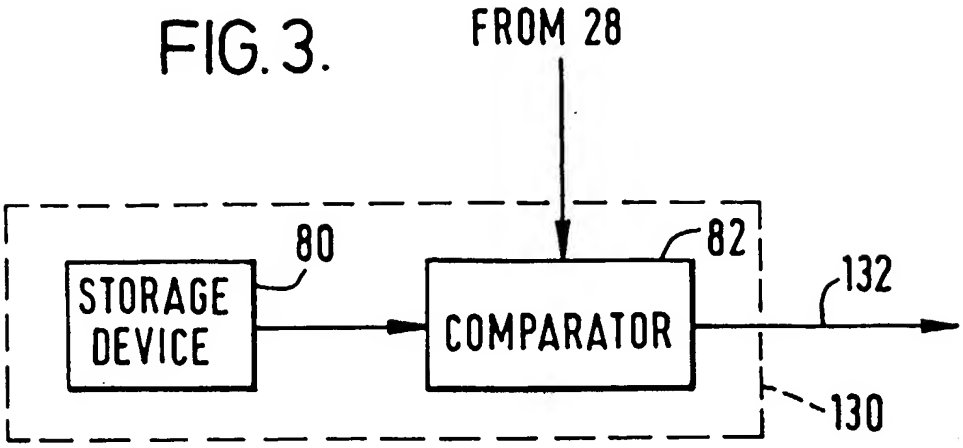
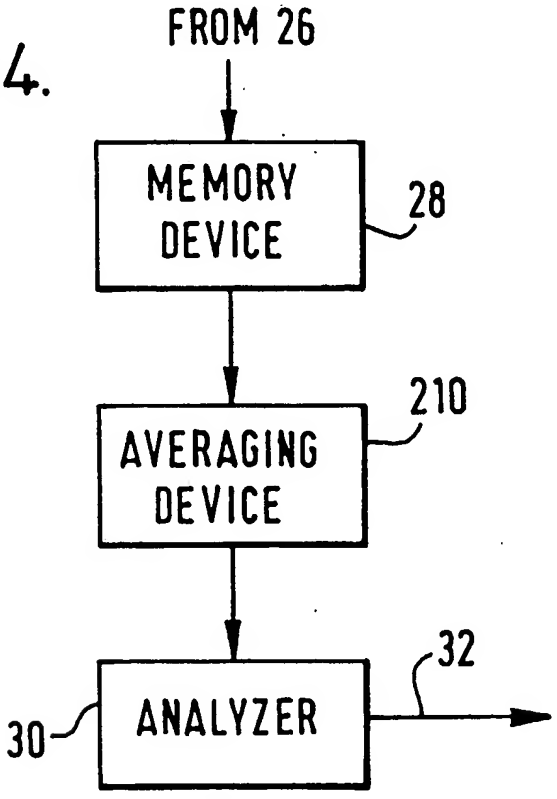

FROM 28
80
82
STORAGE DEVICE
COMPARATOR
132
130

FIG. 4.


FROM 26
MEMORY DEVICE
28
AVERAGING DEVICE
210
ANALYZER
32
30